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Effect of size, shape and hardness of particles in suspension on oral texture and palatability

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Oral texture and consistency perception and preference depend on the size, shape and hardness of the particles in aqueous suspensions. Assessments of suspensions of model particles of garnet, polyethylene and mica showed that fairly large particles can be palatable if shape and hardness constraints are taken into account. Size differences matter more if particles are hard and sharp than if they are soft and rounded.

1. Introduction

The influence of the size, shape and hardness of particles on an individual's interpretation of patterns of stimulation of mechanoreceptors in the oral cavity has not been precisely defined. The confectionery literature views the minimum particle size which can be apprehended by the palate to be somewhere around 25 μ (Hinton, 1970). If the particles of a chocolate are all, or nearly all, reduced below this size, the texture is considered to have reached optimum smoothness for chocolate (Minifie, 1980). It can be generally stated that smaller particle size enhances and 'rounds out' flavor in an individual's opinion of a chocolate. The point of diminishing return is reached at sizes of about 10 μ to 15 μ (Cook, 1972). Chocolate particles are irregular but without sharp edges (Minifie, 1980). In the preparation of toothpaste, by contrast, an average particle size of 5 to 20 μ of alumina

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trihydrate is desirable because large particles produce a gritty sensation in the mouth and can scratch the enamel surface (Wills et al., 1988).

In pharmaceutics, such information is useful in the design of oral dosage formulations, especially the identification of size, shape and hardness of particles that would maximize the acceptability of a suspension by reducing any unpleasant textural sensations. The purpose of the investigation briefly reviewed in this paper was to examine the influence of the size, shape and hardness of the particles in a flavored suspension on orosensory perception and palatability (Tyle et al., 1990).

2. Method

2.1. Materials

Four different particle sizes were examined for each of the three types of prototype material: garnet (Advanced Particle Measurements, Inc., Houston, TX), micronized polyethylene (Allied Signal, Morristown, NJ) and mica particles coated with titanium dioxide (Mearl Corporation, New York, NY). The shapes of the particles of these materials varied from spherical to thin and flat.

Four mixtures of particles having different size distribution were prepared (Table 1). Particle size was determined by laser diffraction (Malvern Instruments Series 2600C droplet and particle sizer). The particles were suspended in syrup bases with two different flavors, grape or raspberry/cherry, to give a concentration of 60 mg of test material per 5 ml.

2.2. Procedure

Twenty-four or 25 adult volunteers participated in a single-blind taste trial of each of four flavored suspensions (garnet/grape flavor, garnet/raspberry-cherry flavor, micronized polyethylene/raspberry-cherry flavor and mica/raspberry-cherry flavor). In each trial, a total of five different samples were evaluated. The four different particle size distributions and a control sample were evaluated in each trial. The control product was the flavored syrup without any particles. Each volunteer tasted and expectorated three particulate samples and the control. Samples in opaque bottles were well shaken immediately prior to dispensing a teaspoonful to each volunteer. Sample order was varied to minimize order biases. Participants consumed unsalted crackers and water between samples to clear their palate. Assessors rated each sample on (a) texture, i.e., the mouthfeel in terms of grittiness; (b) taste, i.e, the pleasantness of the sample; and (c) consistency, i.e., the viscosity of that product. Each characteristic was rated from 1 to 5, 1 being

Table 1
Particle diameter characteristics of the test materials

	Garnet		Micronized polyethylene		Mica platelets coated with titanium dioxide	
	Mean particle diameter (μ)	Span [a]	Mean particle diameter (μ)	Span [a]	Mean particle diameter (μ)	Span [a]
A	5.2	1.5	7.2	1.0	28.1	1.9
B	11.0	1.1	11.8	1.0	29.9	1.6
C	22.0	1.2	14.1	1.2	41.1	1.5
D	33.0	1.0	68.9	1.5	79.6	1.6

[a] Span = D(90) − D(10)/D(50), where D(90) and D(10) are the 90th and 10th centiles of the particle diameters distribution and D(50) is median particle diameter.

gritty and 5 smooth for texture, 1 being very unpleasant and 5 very pleasant for taste and, for consistency, 1 being too thin and 5 standing for too thick. Pleasantness ratings were included when the flavor vehicle was the same for all samples in order to determine whether granule size influenced the perception of taste, aroma or mouthfeel in a way that might affect patient compliance in use of a product. After rating every sample in a trial, respondents were asked for their first choice for palatability, except in the case of garnet particles suspended in grape-flavored base where volunteers chose the top two candidates.

Statistical analysis was performed by Statpad Software program utilizing one-way ANOVA with protected post hoc comparisons and Chi-Squared Test (Snedecor and Cochran, 1980). The analysis was done comparing each sample with another in a given rating category.

3. Results

Garnet particles are generally angular in shape (Fig. 1). Micronized polyethylene is rounded (Fig. 2). Mica platelets coated with titanium dioxide are relatively flat in shape (Fig. 3). On the Mohs' scale of relative hardness, garnet has a hardness of 6.5–7.0, mica is 2.8 and micronized polyethylene is < 2.0, as compared to talc's hardness of 1.0 and diamond's 10 (Weast and Astle, 1981).

For the trial conducted with garnet particles in a grape-flavored base, granule size appeared to be a factor in acceptance ($p < 0.05$). As expected, the control (E) was rated as having the smoothest texture (Table 2). Additionally, Sample A differed from Sample D at $p = 0.16$. The control product (E) had the highest rating for pleasantness of taste (Table 2) although this variation among the samples was not quite significant ($p = 0.061$). The

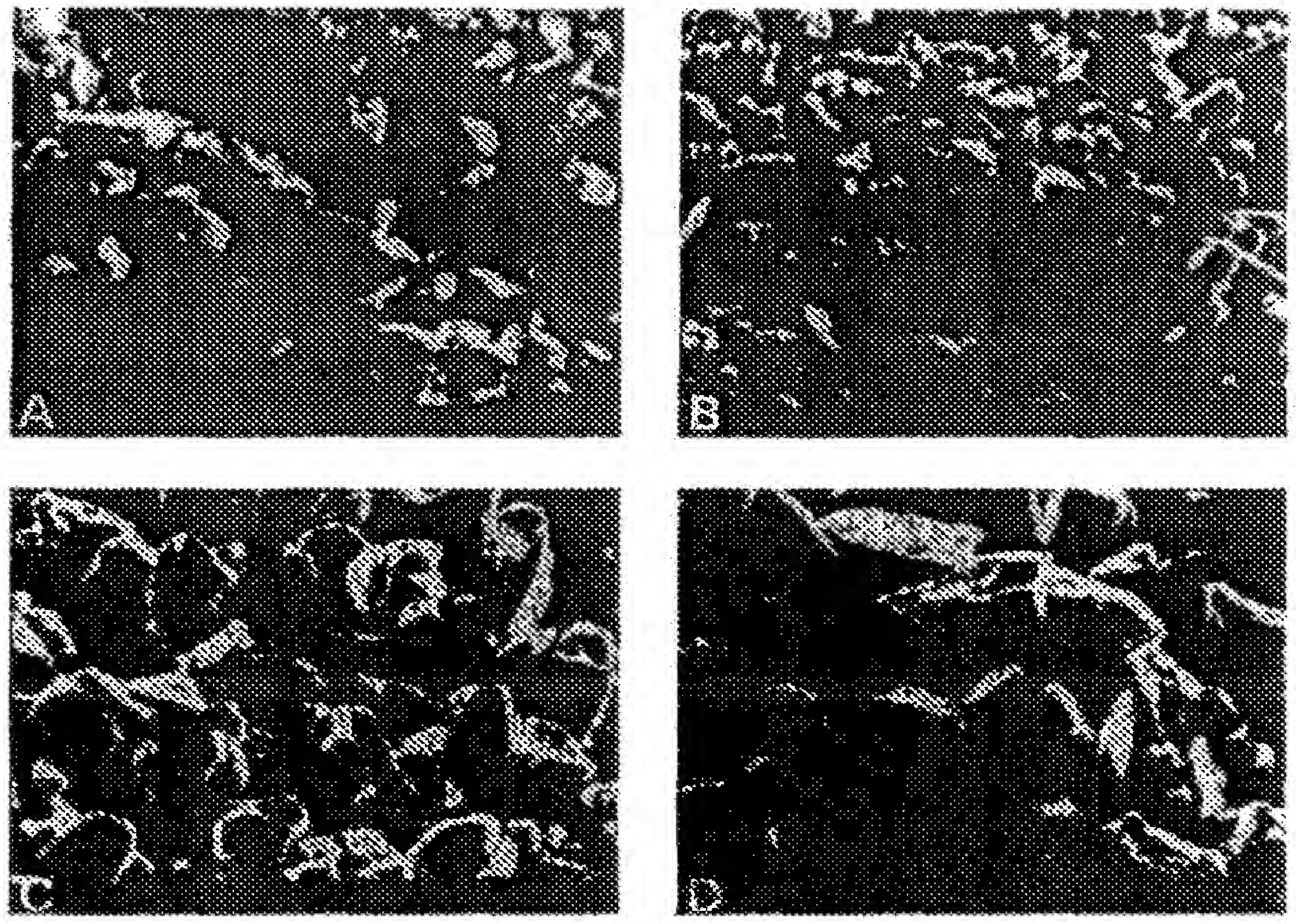

Fig. 1. Scanning electron micrographs of garnet particles. The mean particle sizes are (A) 5.2 μ, (B) 11.0 μ, (C) 22.0 μ and (D) 33.0 μ.

consistency ratings did not vary appreciably among suspensions ($p = 0.77$). The overall preference results were usually consistent with the pleasantness ratings but did not show significant variation in chi-squared tests (Tyle et al., 1990) and so are not presented here.

Participants also seemed to be able to detect the difference in particle size of the garnet samples when presented in a raspberry/cherry-flavored vehicle (Table 3). Samples A and B, which contained the small particles, had higher smoothness ratings than Samples C and D. The control sample (E) was rated smoother than Samples B, C and D at the 95% confidence level. Sample A was smoother than Samples C and D ($p = 0.017$) and Sample B smoother than Sample D ($p = 0.012$). That is, the most acceptable particle size for garnet appeared to be between Samples B and C (mean particle size: 11.0 to 22.0 microns). However, the variation in the pleasantness ratings among samples was not statistically significant ($p = 0.164$). Most consistency ratings were at about the mid-point of 3.0 and so garnet particle size again failed to influence the consistency ratings.

In contrast to the case for garnet, the differences in particle size of polyethylene, or even the presence of polyethylene particles, were apparently

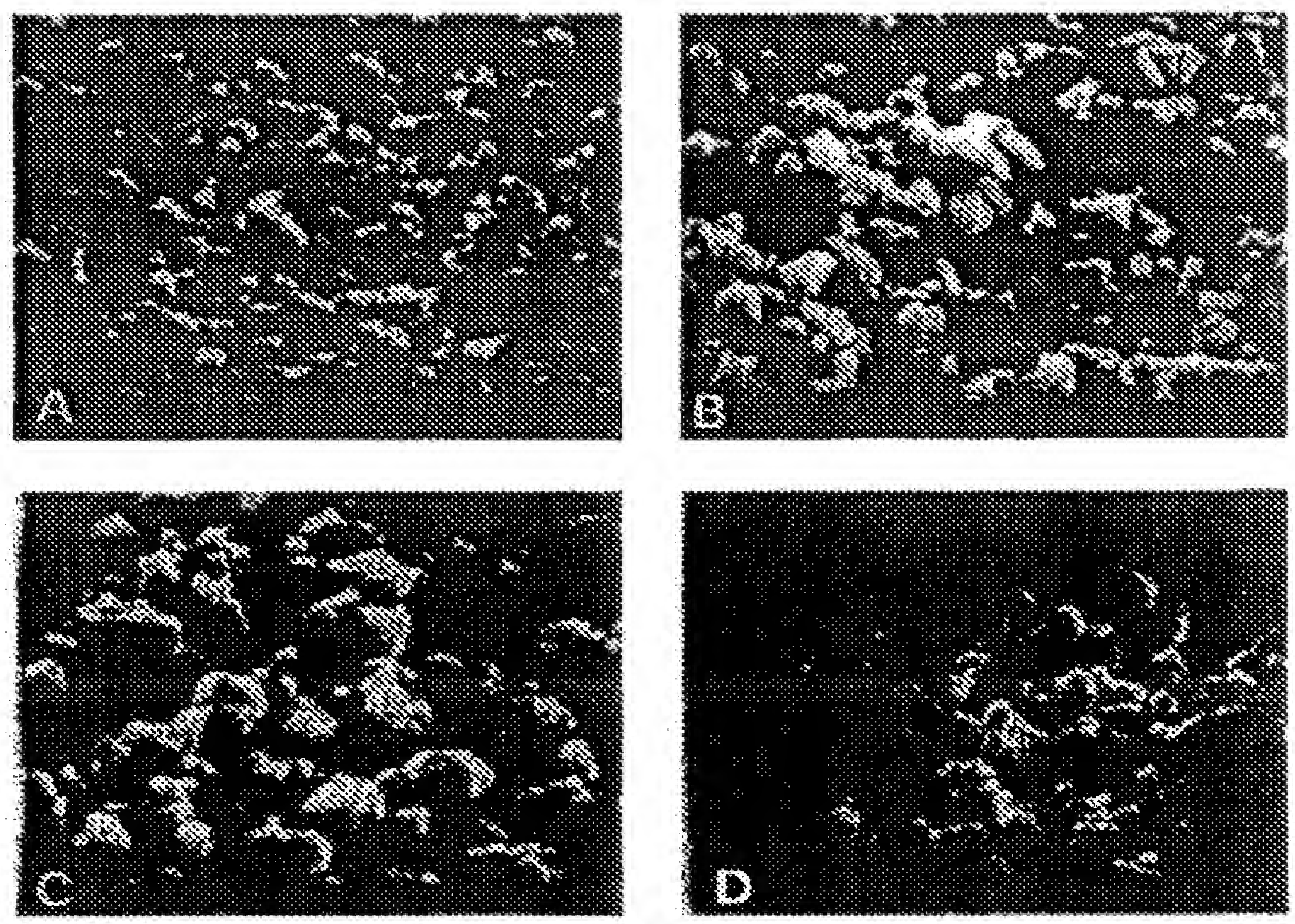

Fig. 2. Scanning electron micrographs of micronized polyethylene particles. The mean particle sizes are (A) 7.2 μ, (B) 11.8 μ, (C) 14.1 μ and (D) 68.9 μ.

not detected by texture ratings, as they did not vary at the 95% confidence level (Table 4). Consistency ratings were similar for all five samples. The raspberry-cherry base alone (Sample E) was more pleasant than Samples A and B ($p = 0.025$). When this control product (E) is removed from the data

Table 2
Ratings (mean and standard deviation) of texture, taste and consistency for garnet particles suspended in grape-flavored base

	Particle suspensions									
	A ($N = 18$)		B ($N = 19$)		C ($N = 20$)		D ($N = 18$)		E ($N = 25$)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Gritty (1)/Smooth (5)	3.7	1.1	3.5	1.2	2.7	1.3	2.9	1.4	4.4	0.7
Too thin (1)/Too thick (5)	3.2	1.0	3.1	0.6	3.1	1.0	3.4	1.0	3.1	0.8
Very unpleasant taste (1) /Very pleasant taste (5)	3.4	0.9	3.2	1.2	3.7	1.2	3.4	1.2	4.1	0.9

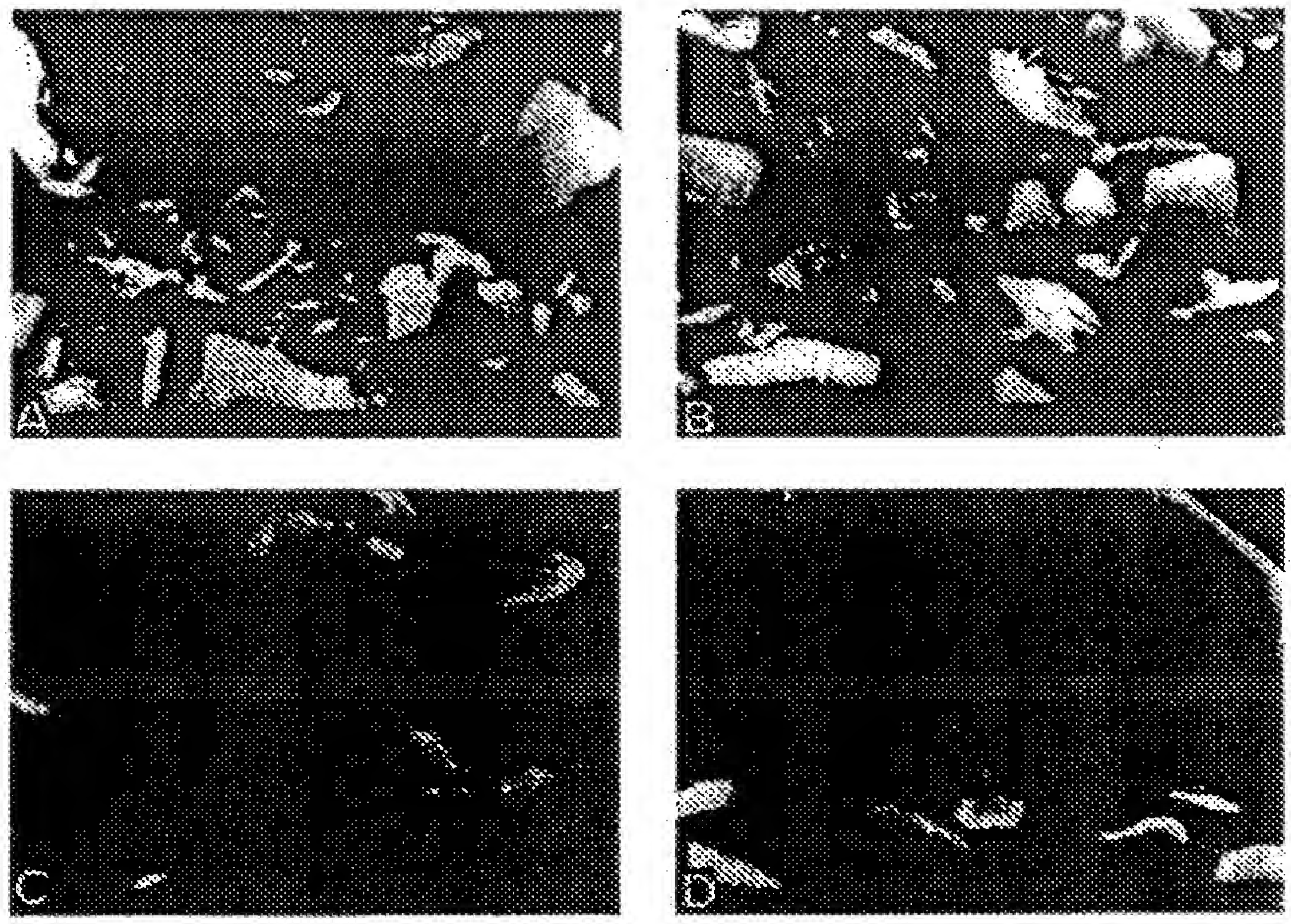

Fig. 3. Scanning electron micrographs of mica particles. The mean particles sizes are (A) 28.1 μ, (B) 29.9 μ, (C) 41.5 μ and (D) 79.6 μ.

set, the only statistical significance is Sample D over Sample A at the $p = 0.006$ level.

The overall preferences were usually consistent with the pleasantness ratings but did not show significant variation (Tyle et al., 1990). Some

Table 3
Ratings (mean and standard deviation) of texture, taste and consistency for garnet particles suspended in raspberry/cherry-flavored base

	Particle suspensions									
	A ($N = 18$)		B ($N = 18$)		C ($N = 28$)		D ($N = 18$)		E ($N = 24$)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Gritty (1)/Smooth (5)	4.2	0.9	3.6	1.2	3.0	1.3	2.3	1.2	4.5	0.8
Too thin (1)/Too thick (5)	3.2	0.8	2.9	0.7	3.6	0.7 [a]	3.1	0.6	3.1	0.6
Very unpleasant taste (1) /Very pleasant taste (5)	3.3	0.6	3.3	1.1	3.5	0.9	3.6	0.8	3.9	0.8

[a] One respondent did not rate consistency.

Table 4
Ratings (mean and standard deviation) of texture, taste and consistency for micronized polyethylene particles suspended in raspberry/cherry-flavored base

	Particle suspensions									
	A ($N = 18$)		B ($N = 18$)		C ($N = 28$)		D ($N = 18$)		E ($N = 24$)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Gritty (1)/Smooth (5)	3.6	1.1	3.9	1.1	4.1	1.0	4.1	0.9	4.5	0.7
Too thin (1)/Too thick (5)	3.2	0.7	3.4	0.8	3.3	0.8	3.5	0.6	3.2	0.6
Very unpleasant taste (1) /Very pleasant taste (5)	2.3	1.2	2.9	1.1	3.1	1.2	3.6	0.7	3.8	0.9

Table 5
Ratings (mean and standard deviation) of texture, taste and consistency for mica platlets coated with titanium dioxide suspended in raspberry/cherry-flavored base

	Particle suspensions									
	A ($N = 18$)		B ($N = 18$)		C ($N = 28$)		D ($N = 18$)		E ($N = 24$)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Gritty (1)/Smooth (5)	4.0	1.0	4.1	1.0	3.8	1.2	3.6	0.9	4.4	0.7
Too thin (1)/Too thick (5)	3.6	0.8	3.4	0.8	3.3	0.8	3.2	0.7	3.2	0.6
Very unpleasant taste (1) /Very pleasant taste (5)	3.7	1.0	3.8	1.0	3.5	1.2	3.3	1.0	3.7	1.1

assessors commented on the plastic taste, especially those tasting samples A, B or C. The comments included 'off-flavor' and 'very bitter after-taste'. It appears that each of the four particle sizes (which arrived in four discrete samples) contributed to the overall taste detrimentally.

All sizes of mica particles yielded acceptable texture ratings (Table 5); the decrease in rating with increase of average particle size was not statistically significant ($p = 0.116$). All samples had good ratings on taste ($p = 0.745$). Consistency ratings for all samples were similar ($p = 0.467$). The overall preference results were usually consistent with the pleasantness ratings (Tyle et al., 1990).

4. Discussion

With hard garnet and mica particulates, the data show that as particle size increases, the texture rating decreases, i.e., samples are perceived as increas-

ingly gritty. The trend seems reversed for relatively soft polyethylene particulates.

There was no effect observed on the thickness ratings of the particulates suspended in the flavored base at this concentration. Therefore viscosity is unlikely to play a part in particle perception in these samples. Ratings of grittiness/smoothness were definitely influenced by particle size when particles were hard and irregular in shape. This texture effect of garnet may have a marginal effect on acceptability of a flavored suspension at this concentration. Particles up to about 80 μ are not perceived as gritty if they are generally soft and rounded (polyethylene) or relatively hard and flat (mica). On the other hand, with hard and angular particles, like garnet, grittiness is evident above a particle size range of about 11–22 μ. Hence consumers should be able to tell differences in size, shape and hardness between particles in medicines and foods, such as starch granules and particulate cellulose.

References

Cook, L.R., 1972. Chocolate production and use (Chapter 10, p. 210). New York: Book for Industry, Inc.

Hinton, C.J., 1970. In: C.D. Pratt, E. de Vadetzsky, K.E. Landwill, K.E. McCloskey and H.W. Schuemann (Eds.), Twenty years of confectionery and chocolate progress (Chapter 13, p. 111). Westport, CT: Avi Publishing Co.

Miller, I.J. and F.E. Reedy, Jr., 1990. Variations in human taste bud density and taste intensity perception. Physiology & Behavior, 47, 1213–1219.

Minifie, B.W., 1980. Chocolate, cocoa and confectionery: Science and technology (p. 117 and 649). Westport, CT: Avi Publishing Co.

Snedecor, G.W. and W.G. Cochran, 1980. Statistical methods (7th ed.) (Chapter 5, pp. 64–82 and Chapter 12, pp. 215–237). Ames, IA: Iowa State University Press.

Tyle, P., C. Kuenn, L. Geier and P. Jarosz, 1990. Effect of size, shape and hardness of particles in suspensions on oral palatability. Drug Development & Industrial Pharmacy, 16, 1339–1364.

Wills, K., T. Emery, I. Thompson and R. Giles, 1988. Alumina trihydrate use in toothpaste. Manufacturing Chemist 10, 41–45.

Weast, R.C. and M.J. Astle, 1981. CRC handbook of chemistry and physics (61st ed.) (p. F–24). Boca Raton, FL: CRC Press, Inc.